Live Bait vs Dead Bait Evaluations of US Pelagic Longline Fishing Incidental Catch Rates of Billfish in the Gulf of Mexico

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Of interest is the potential for reduction in incidental catch of billfish (Blue Marlin, White Marlin, and Sailfish) in the US Gulf of Mexico pelagic longline fleet that could be attained by disallowing the use of live bait in pelagic longline fishing in the Gulf of Mexico. Of subsequent interest, is the potential effect of such an action on catches of marketed species and on catches of undersized swordfish. Only the first question is addressed in this document.

Two data sets are available with which to examine the potential for reduction of billfish catch by eliminating live bait fishing with longlines. These are the pelagic logbook data and the pelagic longline observer data. For the purposes of analysis, logbook data were considered for 1992-1998 (normal quality assurance steps for the 1999 logbook data are not expected to be completed until June 2000), while observer data were considered for 1992-1999.

Logbook Evaluations. The logbook data provide a measure of the total reported pelagic longline fishing effort using live or dead bait in the Gulf of Mexico (Figure 1). Of the approximately 21,000 hauls reported from the Gulf of Mexico between 1992 and 1998, approximately 13% were reportedly made fishing with live bait. The proportion of live bait fishing operations made in the western Gulf of Mexico was reportedly higher, 17% , although the total reported effort in the western zone (9,944 hauls total) was lower than in the eastern zone.

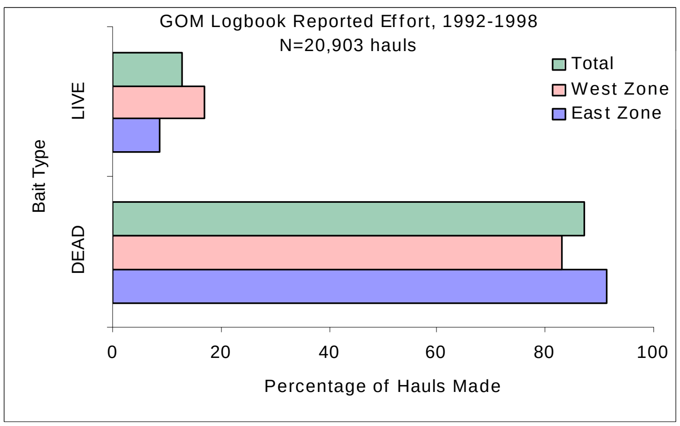

Figure 1*. Logbook reported effort (hauls) from the Gulf of Mexico pelagic longline fleet by bait type and fishing zone.*

Overall, the proportion of hauls in which billfish were reported caught was relatively low, less than 1 in 4, regardless of bait type (Figure 2). For live bait hauls, however, the reported proportion of sets with billfish catch was higher (24%) than for hauls made not using live bait (16.5%). For hauls in which at least 1 billfish was reported caught, the distribution of reported catch per haul is much more similar between bait types (Figure 3), although there is some indication of a relatively higher nominal frequency of billfish per haul in live bait operations. In a nominal sense, bait type is indicated as a factor of possible importance in explaining these patterns.

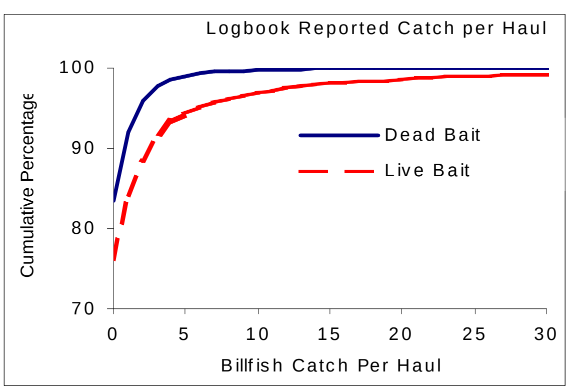

Figure 2. *Logbook reported catch of billfish per haul, by bait type fished. On average fewer than 1 in 4 hauls report any catch of billfish, although live bait hauls have the higher reported proportion of hauls with billfish catch.*

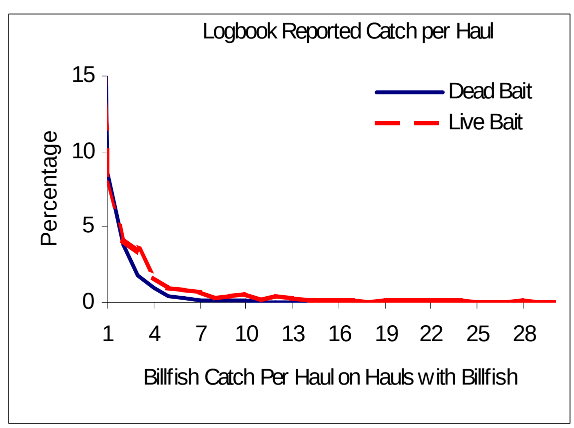

Figure 3. *Logbook reported frequency of hauls catching the number of billfish indicated.*

To test if these patterns could be explained by other factors as well as bait type (live, dead), we applied Generalized Linear Models of the probability of billfish capture and of the catch of billfish on positive hauls, controlling for year (1982-1998), calendar quarter, fishing zone (east Gulf vs west Gulf), lite stick usage (none, moderate, high), time of set (day, night), hook density (low, high), and depth of set (shallow, deep), following the conventions defined in Ortiz *et al* (1999, ICCAT Working Document SCRS/99/87, SFD Contribution SFD-98/99-55, available from the Southeast Fisheries Science Center). A forward entry, stepwise procedure was used for evaluating the significance and order of entry for factors used in these models. A base model with main effects of year, quarter, and fishing zone was first fit to the data. Factors were then entered into the model in order of largest improvement in log likelihood per degree of freedom provided that the improvement in fit as indicated by improvement in the log likelihood per degree of freedom was at least 2. Two-way interactions were admitted to the model if the log likelihood criterion was met and if the interaction accounted for at least an additional 5% of the deviance explained. For the proportion of positive catch hauls, the data were modeled as a binomial response with a logit link, while for the positive catch hauls, catch was modeled as a Poisson response with log link and an offset of log(hooks fished). The resulting model for positive catch hauls (Table 1) included the main effects of year, quarter, zone, bait, hook density, time of fishing, and depth of fishing plus an interaction term for bait x depth of fishing. The resulting model for the proportion of hauls which successfully caught billfish included only the main effects of year, quarter, fishing zone, and bait (Table 2). Model predicted marginal means from the final models with associated 80% confidence regions were used to judge the effect of live vs dead bait on the probability of capture and the catch level per successful set conditioned on the other effects contained in the model. In both cases (see Table 3), the effect of bait type is estimated to have a significant, measurable effect on catch per hook on hauls with billfish catch and on the proportion of hauls with billfish catch. From these model-predictions, overall catch rates by bait type can be estimated as the product of the two components. For live bait hauls, the model-predicted average catch rate (BIL/1000 hooks) is 1.06 (5.0*.21) while for dead bait hauls, the model predicted average is 0.56 (3.6*.16).

Table 3. *Marginal mean estimates from Generalized Linear Models applied to logbook data of a) catch per hook on successful hauls and b) proportion of hauls with catch of billfish .*

a:Catch per hook on hauls with billfish catch				
Effect	BAIT	BIL/hook	Lower80%	Upper80%
BAIT	DEAD	0.0036	0.0034	0.0038
BAIT	LIVE	0.0050	0.0044	0.0057
b:Proportion of hauls which catch billfish				
Effect	BAIT	Proportion	Lower80%	Upper80%
BAIT	DEAD	0.1568	0.1523	0.1615
BAIT	LIVE	0.2117	0.1989	0.2252

Observer Evaluations. The observer data provide a sample of the pelagic longline fishing effort using live or dead bait in the Gulf of Mexico. Of the approximately 1,200 hauls observed from the Gulf of Mexico between 1992 and 1999, about 21% were made fishing with live bait. The proportion of live bait fishing operations observed in the western Gulf of Mexico was higher, 24% , and the total observed effort in the western zone (680 hauls total) was slightly higher than in the eastern zone. Although these proportions are somewhat different, they are in general agreement with the logbook census of reported effort, and represent about 6% of the effort reported from the Gulf during 1992-1998.

Observers identified 1827 billfish to species level (BUM, WHM, or SAI) on Gulf of Mexico hauls. Additional catches of 168 unidentified billfish were observed. Unidentified billfish can include swordfish; however, examination of the data suggests that the inclusion of swordfish among unidentified billfish is minimal. Among unidentified billfish, 49% were released dead, 40% were released alive and only 11% (18 fish) were lost. Although there are certainly regulatory and other reasons to intentionally release swordfish, presumably an intentional release is less likely to occur until the fisherman has established either that the fish is not a swordfish or that the fish is a swordfish but cannot be retained. Furthermore, the overall proportion of hauls in which identified billfish were observed caught was lower for dead bait hauls (about 39%), but higher in live bait hauls (about 66%, Figure 5). When unidentified billfish are included in the calculations (Figure 6), these proportions change very little; for dead bait hauls, the proportion of hauls with at least 1 billfish in the catch increases to 41% overall while for live bait hauls, the proportion increases slightly to about 67%.

For hauls in which at least 1 billfish was observed caught, the distribution of observed catch per haul is much more similar between bait types (Figures 7 and 8) and between billfish classifications. As in the logbook evaluations, in a nominal sense, bait type is indicated as a factor of possible importance in explaining these patterns. Again, examination of the data suggests that unidentified billfish are more similar to identified billfish than to swordfish. Among hauls in which at least 1 fish

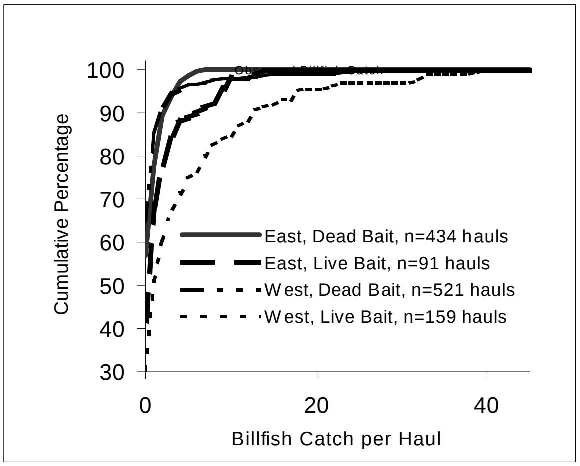

Figure 5. *Observed catch of identified billfish (BUM, WHM, and SAI) per haul, by bait type fished.*

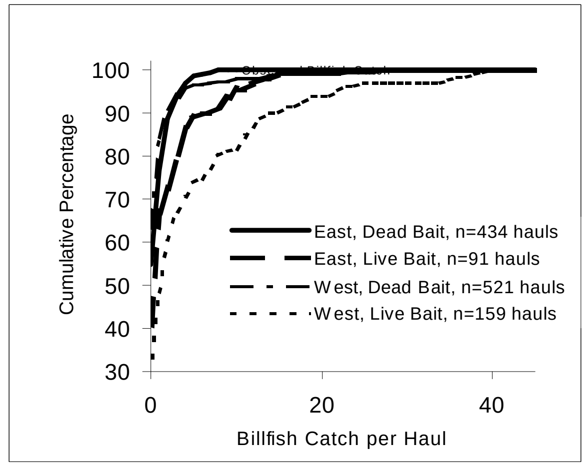

Figure 6. *Observed catch of identified billfish (BUM, WHM, and SAI) plus unidentified billfish per haul, by bait type fished.*

from the relevant category was observed, the overall catch rate ratio for live bait relative to dead bait was 2.2 for identified billfish, 1.9 for the 168 unidentified billfish, and 0.2 for swordfish.

As for the logbook evaluations, Generalized Linear Models were applied to evaluate if these nominal patterns could be explained by other factors as well as bait type for observer data. Given the empirical evidence suggesting that swordfish were not a major component of unidentified billfish, the analyses were performed using both identified billfish (BUM, WHM, and SAI) and unidentified billfish.

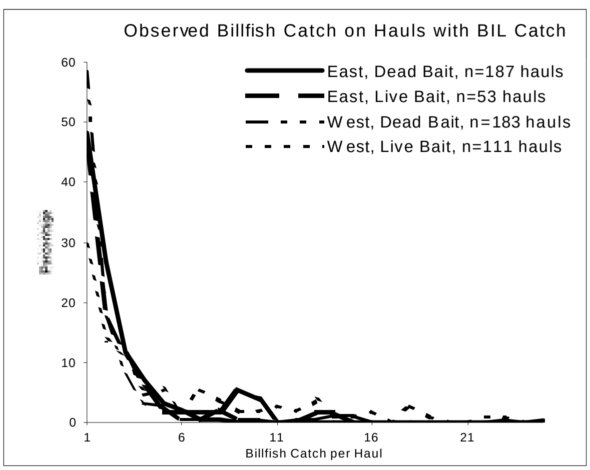

Figure 7. *Observed catch of identified billfish (BUM, WHM, and SAI) per haul,on hauls where billfish were caught by bait type fished.*

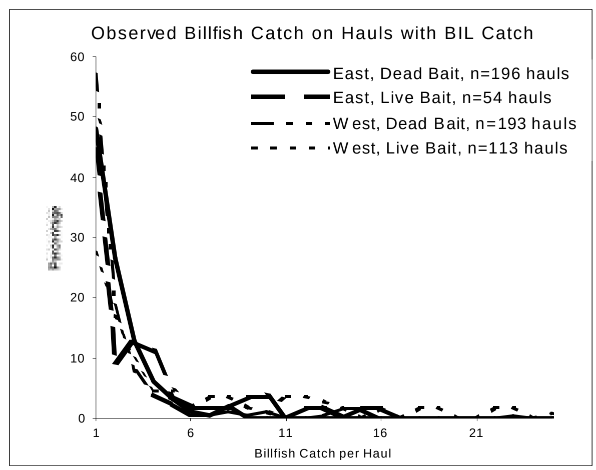

Figure 8. *Observed catch of identified billfish (BUM, WHM, and SAI) plus unidentified billfish per haul,on hauls where billfish were caught by bait type fished.*

<ins>Identified Billfish Plus Unidentified Billfish.</ins> The resulting model for positive catch hauls for the identified billfish plus unidentified billfish observations (Table 4) included the main effects of year, quarter, zone, bait, hook density, and lites plus interaction terms for fishing zone x lites, quarter x fishing zone, year x bait and year x quarter. As the observations were too sparse to permit estimating marginal means from this model with the interaction terms year x bait and year x quarter modeled as fixed effects, the interactions in this case were modeled as random effects. The resulting model for the proportion of hauls which successfully caught identified billfish plus unidentified billfish included the main effects of year, quarter, fishing zone, time of set, hook density, bait and lites; no interaction terms contributed significantly to the model (Table 5). Model predicted marginal means from the final models with associated 80% confidence regions were used to judge the effect of live vs dead bait on the probability of capture and the catch level per successful set conditioned on the other effects contained in the model. Bait was judged to have a significant, measurable effect on the probability of capture of identified billfish plus unidentified billfish

(proportion positive hauls) as well as for catch per hook for hauls on which identified billfish plus unidentified billfish were caught. From these model-predictions, overall catch rates by bait type can be estimated as the product of the two components. In this case, the average catch per 1000 hooks fished on positive catch hauls was taken as the average across bait in Table 6 (3.1 billfish /1000 hooks). For live bait hauls, the model-predicted average catch rate (BIL/1000 hooks) is 1.98 (3.5*0.56) while for dead bait hauls, the model predicted average is 1.19 (2.7*0.44).

Table 6. *Marginal mean estimates from Generalized Linear Models applied to observer data of a) catch per hook on successful hauls for identified billfish (BUM, WHM, SAI) plus unidentified billfish and b) proportion of hauls with catch of identified billfish (BUM, WHM, SAI) plus unidentified billfish .*

a:Catch per hook on observed hauls with identified plus unidentified billfish catch

Effect BAIT	BIL/hook	Lower80%	Upper80%
BAIT DEAD	0.0027	0.0018	0.0038
BAIT LIVE	0.0035	0.0023	0.0054

b:Proportion of observed hauls which catch identified plus unidentified billfish

Effect BAIT	Proportion	Lower80%	Upper80%
BAIT DEAD	0.4399	0.3981	0.4826
BAIT LIVE	0.5645	0.4854	0.6404

Expected Reduction in Billfish Catch Based on Catch Rate Comparisons Although the predicted average catch rate for live bait hauls from the above analyses range from about 1.7 to 1.9 times that of dead bait hauls across the data sets evaluated, because the amount of fishing effort in the Gulf using live bait is a small proportion of the total, the expected reduction in billfish catch due to a possible rulemaking which would disallow the use of live bait fishing practices in the Gulf of Mexico will be less than estimated by a direct comparison of catch rates. The expected reduction is more accurately predicted by comparing the weighted average catch rate between bait types with the dead bait catch rate average. Here, the weights reflect the relative proportion of live bait effort compared to dead bait effort in the Gulf of Mexico. From Figure 1, approximately 13% of the Gulf-wide effort over years 1992-1998 was reported as live bait effort. An expected average proportional reduction in billfish catch can be estimated as:

$$1-[(Ef_{live}CR_{dead} + f_{dead}CR_{dead})/(f_{live}CR_{live} + f_{dead}CR_{dead})],$$

where E represents the expected change in effort fished by the historical live bait fleet after transitioning to dead bait fishing methods, f_{live} is the fraction of total effort historically fishing with live bait, CR_{live} is the expected average catch rate of billfish for live bait fishing based on the historical observations, f_{dead} ($=1-f_{live}$) is the fraction of total effort historically fishing with other than live bait, and CR_{dead} is the expected average catch rate of billfish for other than live bait fishing based on the historical observations. Thus, assuming that live bait effort converts 1:1 to dead bait effort (i.e. setting E=1), based on logbook analysis results, for example, the expected reduction due to disallowing live bait in the Gulf would thus be:

$1-[.56/(.13*1.06 + .87*.56)] = 0.104$ or about 10% reduction, provided that the live bait effort converts 1:1 to dead bait effort.

If, on the other hand, live-bait effort were to be removed from the fishery (and not replaced, i.e. setting E=0), then using the same data set results, the expected reduction would be estimated as:

$1-[.87*.56/(.13*1.06 + .87*.56)] = 0.220$ or about 22% reduction provided live bait effort is removed from the fishery.

An additional possibility is that live bait effort would convert to dead bait fishing behavior, but increase in effort fished compensating for the time no longer used in catching bait. For fishing trips made using live bait practices, some part of the fishing trip is spent obtaining live bait. Information from logbook reports from 1996-1998 indicate that on average, vessels reporting trips using live bait exclusively averaged fewer hauls per trip and more days at sea than did vessels reporting using dead bait. For vessel trips fishing exclusively dead bait, an average of 6.8 hauls over an average of 14.2 days were reported (.48 hauls per trip-day) while for vessel trips reporting exclusively live bait, an average of 6 hauls over an average of 17.1 days were reported (.35 hauls per trip-day). The expected proportional reduction in billfish catch following a possible rulemaking disallowing live bait fishing by pelagic longliners in the Gulf of Mexico may be decreased if that segment of the fleet employing live bait were to replace days spent obtaining bait with additional sets. An estimate of the potential effort increase for this fleet segment is the ratio of average hauls per trip day (*i.e.* .48/.35 = 1.37). An alternative estimate can be made from the observer data set wherein the observed average number of hauls per trip made on trips exclusively using live bait was 4.4 while the average number on trips exclusively using dead bait was 7.0 (Figure 9). As trip length was not easily calculated from these data, it is not reported here.

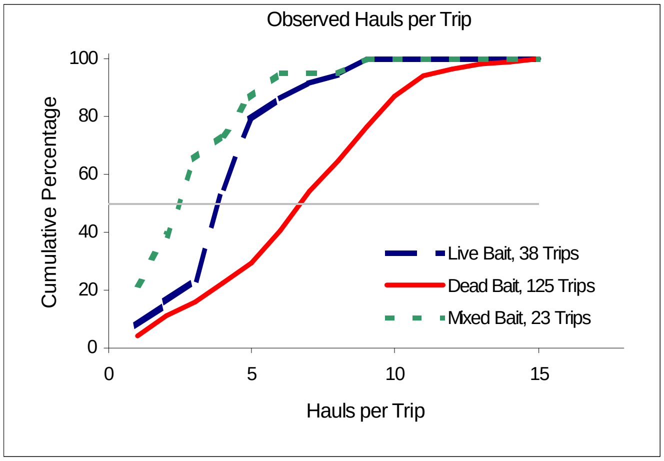

Figure 9. *The cumulative distribution of observed Gulf of Mexico hauls made per trip by US pelagic longline vessels using different bait types.*

The ratio of average hauls per trip in dead bait compared to live bait trips from these data is 1.58, which represents another estimate of potential increase in effort (hauls per trip) for the live bait fleet after transitioning to dead bait fishing behavior.

An alternative estimate of potential reduction taking into account the possibility that effort in the historical live bait fleet increases to be more in line with the haul per trip day average for dead bait reported trips (i.e. setting E=1.58) would be:

1-[(1.58*.13*.56 + .87*.56)/(.13*1.06 + .87*.56)] = 0.036 or about a 4% reduction. Higher potential reductions would result from lower expected effort changes and vice versa.

Expected reductions in BIL catch based on the catch rate comparisons across the data sets analyzed and based on the three assumptions about future behavior of the historical live-bait fishing effort in the Gulf of Mexico, outlined above, are presented in Table 7. The predictions range from ~2% to ~30% potential reductions in BIL catch depending on data set and assumptions about future effort levels for the fleet affected during the process of converting to dead bait effort. The logbook and observer data using identified and unidentified billfish provide generally consistent predictions regarding relative potential reductions in billfish catch. However, this could be coincidental; the logbook and observer data do produce differing results regarding the overall scale of billfish catch rates.

Table 7. *Expected reductions in billfish catch resulting from a possible rulemaking which would eliminate the practice of live bait fishing by pelagic longline vessels in the Gulf of Mexico, under different assumptions about the future behavior of the live bait fishing effort as estimated from several data sources.*

Data Source	Potential Reductions in BIL Catch Given Assumption Listed			
	Unweighted Catch Rate Ratio	Reduction a	Reduction b	Reduction c
Logbooks	47.2%	22.0%	10.4%	3.6%
Observers, Identified + Unidentified BIL	39.9%	30.3%	12.1%	1.5%

Unweighted Catch Rate Ratio does not take into account the relative proportion of effort that has been historically used for live bait fishing versus dead bait fishing. As an estimator for overall billfish catch reduction, this is biased high. This ratio is only applicable as the reduction in billfish catch of a given set if dead bait is used rather than live bait.

Reduction a takes the relative proportion of live bait fishing into account, but assumes that the historical live bait fishing effort will be removed from the fleet

Reduction b takes the relative proportion of live bait fishing into account, and assumes that the historical live bait fishing effort will convert to dead bait fishing effort 1:1 (i.e. will not convert time spent on a trip collecting live bait to dead bait fishing effort).

Reduction c takes the relative proportion of live bait fishing into account, and assumes that the historical live bait fishing effort will convert to dead bait and increase effort by the observed ratio of average hauls per trip fishing with dead bait to the observed hauls per trip fishing with live bait (58% increase in the effort made by the live bait fleet).

Table 1. *Generalized linear model selection procedure results for positive catch per haul data from the pelagic logbooks. In this case, the catch data are modeled as a Poisson distributed response with a log link and an offset of log(hooks fished).*

LOGBOOK positives		**BILLFISH**				
model	***df***	***deviance***	***dev/df***	***chg dev/df***	***LL***	***chg LL/DF***
(null)	3646	11392.63	3.12		531.07	
year quarter zone (base case)	3636	10174.94	2.80		1139.91	
year quarter zone (base case)	3636	10174.94	2.80		1139.91	
year quarter zone bait	3635	9291.33	2.56	0.24	1581.72	441.81
year quarter zone hookdense	3635	9925.96	2.73	0.07	1264.40	124.49
year quarter zone time	3635	10164.50	2.80	0.00	1145.13	5.22
year quarter zone lites	3259	8944.63	2.74	0.05	1691.30	1.46
year quarter zone depth	3635	10173.47	2.80	0.00	1140.64	0.73
year quarter zone bait	3635	9291.33	2.56		1581.72	
year quarter zone bait hookdense	3634	8867.21	2.44	0.12	1793.78	212.06
year quarter zone bait time	3634	9195.43	2.53	0.03	1629.67	47.95
year quarter zone bait depth	3634	9264.33	2.55	0.01	1595.22	13.50
year quarter zone bait lites	3258	7781.01	2.39	0.17	2273.11	1.83
year quarter zone bait hookdense	3634	8867.21	2.44		1793.78	
year quarter zone bait hookdense time	3633	8856.34	2.44	0.00	1799.21	5.44
year quarter zone bait hookdense depth	3633	8861.93	2.44	0.00	1796.42	2.64
year quarter zone bait hookdense lites	3257	7752.28	2.38	0.06	2287.48	1.31
year quarter zone bait hookdense time	3633	8856.34	2.44		1799.21	
year quarter zone bait hookdense time depth	3632	8850.43	2.44	0.00	1802.17	4.20
year quarter zone bait hookdense time lites	3256	7751.65	2.38	0.06	2287.79	1.31
year quarter zone bait hookdense time depth	3632	8850.43	2.44		1802.17	
year quarter zone bait hookdense time depth lites	3255	7749.61	2.38	0.06	2288.81	1.29
year quarter zone bait hookdense time depth	3632	8850.43	2.44		1802.17	
year quarter zone bait hookdense time depth bait*depth	3631	8600.60	2.37	0.07	1927.08	124.92
year quarter zone bait hookdense time depth bait*hookdense	3631	8704.20	2.40	0.04	1875.28	73.12
year quarter zone bait hookdense time depth bait*zone	3631	8719.65	2.40	0.04	1867.55	65.39
year quarter zone bait hookdense time depth bait*quarter	3629	8742.17	2.41	0.03	1856.30	18.04
year quarter zone bait hookdense time depth bait*time	3631	8846.20	2.44	0.00	1804.28	2.11

FINAL MODEL:

year quarter zone bait hookdense time depth bait*depth

Table 2. *Generalized linear model selection procedure results for proportion positive hauls from the pelagic logbooks. In this case, the data (successful hauls) are modeled as a Binomial distributed response with a logit link.*

LOGBOOK proportion positive		**BILLFISH**			
model	**df**	**deviance**	**dev/df**	**LL**	**change LL/DF**
(null)	20921	19374.76	0.93	-9687.38	
year quarter zone (base case)	20908	18896.84	0.90	-9448.42	
year quarter zone (base case)	20908	18896.84	0.90	-9448.42	
year quarter zone bait	20907	18847.91	0.90	-9423.96	24.47
year quarter zone depth	20907	18893.06	0.90	-9446.53	1.89
year quarter zone lites	18766	16889.20	0.90	-8444.60	0.47
year quarter zone hookdense	20907	18896.27	0.90	-9448.14	0.29
year quarter zone time	20907	18896.74	0.90	-9448.37	0.05
year quarter zone bait	20907	18847.91	0.90	-9423.96	
year quarter zone bait hookdense	20906	18845.55	0.90	-9422.77	1.18
year quarter zone bait depth	20906	18846.73	0.90	-9423.37	0.59
year quarter zone bait lites	18765	16792.96	0.89	-8396.48	0.48
year quarter zone bait time	20906	18847.45	0.90	-9423.72	0.23
year quarter zone bait	20907	18847.91	0.90	-9423.96	
year quarter zone bait year*zone	20903	18795.67	0.90	-9397.84	6.53
year quarter zone bait quarter*zone **	20904	18813.47	0.90	-9406.74	5.74
year quarter zone bait year*quarter	20889	18750.37	0.90	-9375.19	2.71
year quarter zone bait year*bait	20901	18823.65	0.90	-9411.82	2.02
year quarter zone bait zone*bait	20906	18845.68	0.90	-9422.84	1.12
year quarter zone bait quarter*bait	20906	18846.76	0.90	-9423.38	0.58

** model did not converge

FINAL MODEL: year quarter zone bait

Table 4. *Generalized linear model selection procedure results for positive catch per haul from observer data using identified billfish (BUM, WHM, and SAI) plus unidentified billfish. In this case, the catch data are modeled as a Poisson distributed response with a log link and an offset of log(hooks fished).*

OBSERVER positives	BILLFISH				
model	**df**	**deviance**	**dev/df**	**LL**	**change LL/DF**
null	555	2550.42	4.60	559.70	
Year quarter zone	544	1800.74	3.31	934.54	
Year quarter zone bait	543	1677.72	3.09	996.05	61.51
Year quarter zone hookdense	543	1739.09	3.20	965.37	30.83
Year quarter zone lites	542	1709.26	3.15	980.28	22.87
Year quarter zone time	543	1783.25	3.28	943.29	8.75
Year quarter zone depth	543	1800.35	3.32	934.74	0.20
Year quarter zone bait	543	1677.72	3.09	996.05	
Year quarter zone bait hookdense	542	1588.88	2.93	1040.47	44.42
Year quarter zone bait lites	541	1608.23	2.97	1030.80	17.37
Year quarter zone bait time	542	1677.37	3.09	996.23	0.18
Year quarter zone bait depth	542	1677.43	3.09	996.19	0.14
Year quarter zone bait hookd	542	1588.88	2.93	1040.47	
Year quarter zone bait hookdense lites	540	1557.38	2.88	1056.22	7.88
Year quarter zone bait hookdense time	541	1584.63	2.93	1042.60	2.13
Year quarter zone bait hookdense depth	541	1588.16	2.94	1040.83	0.36
Year quarter zone bait hookdense lites	540	1557.38	2.88	1056.22	
Year quarter zone bait hookdense lites depth	539	1556.51	2.89	1056.66	0.44
Year quarter zone bait hookdense lites time	539	1556.93	2.89	1056.45	0.23
Year quarter zone bait hookdense lites	540	1557.38	2.88	1056.22	
Year quarter zone bait hookdense lites zone*lites	538	1470.32	2.73	1099.75	21.77
Year quarter zone bait hookdense lites quarter*zone	537	1437.21	2.68	1116.30	20.03
Year quarter zone bait hookdense lites year*bait	534	1421.58	2.66	1124.12	11.32
Year quarter zone bait hookdense lites zone*hookdense	539	1540.65	2.86	1064.58	8.36
Year quarter zone bait hookdense lites quarter*bait	537	1525.55	2.84	1072.13	5.30
Year quarter zone bait hookdense lites year*zone	533	1483.90	2.78	1092.96	5.25
Year quarter zone bait hookdense lites hookdense*lites	538	1538.22	2.86	1065.80	4.79
Year quarter zone bait hookdense lites year*quarter	520	1380.63	2.66	1144.60	4.42
Year quarter zone bait hookdense lites zone*bait	539	1549.51	2.87	1060.16	3.94
Year quarter zone bait hookdense lites year*hookdense	534	1525.99	2.86	1071.92	2.62
Year quarter zone bait hookdense lites quarter*lites	534	1529.52	2.86	1070.15	2.32
Year quarter zone bait hookdense lites year*lites	526	1499.66	2.85	1085.08	2.06
Year quarter zone bait hookdense lites quarter*hookdense	537	1548.59	2.88	1060.62	1.47
Year quarter zone bait hookdense lites bait*hookdense	539	1555.18	2.89	1057.32	1.10
Year quarter zone bait hookdense lites bait*lites	539	1557.11	2.89	1056.36	0.14
Year quarter zone bait hookdense lites zone*lites	538	1470.32	2.73	1099.75	
Year quarter zone bait hookdense lites zone*lites quarter*zone	535	1361.04	2.54	1154.39	18.21
Year quarter zone bait hookdense lites zone*lites year*bait	532	1359.20	2.55	1155.31	9.26
Year quarter zone bait hookdense lites zone*lites year*quarter	518	1270.94	2.45	1199.44	4.98

continued on next page

Table 4 (continued). *Generalized linear model selection procedure results for positive catch per haul from observer data using identified billfish (BUM, WHM, and SAI) plus unidentified billfish. In this case, the catch data are modeled as a Poisson distributed response with a log link and an offset of log(hooks fished).*

OBSERVER positives		BILLFISH			
model	**df**	**deviance**	**dev/df**	**LL**	**change LL/DF**
Year quarter zone bait hookdense lites zone*lites quarter*zone	535	1361.04	2.54	1154.39	
Year quarter zone bait hookdense lites zone*lites quarter*zone year*bait529	529	1255.90	2.37	1206.96	8.76
Year quarter zone bait hookdense lites zone*lites quarter*zone year*quarter	515	1191.29	2.31	1239.27	4.24
Year quarter zone bait hookdense lites zone*lites quarter*zone year*bait	529	1255.90	2.37	1206.96	
Year quarter zone bait hookdense lites zone*lites quarter*zone year*bait year*quarter	509	1106.20	2.17	1281.81	4.90

Final Model BIL = Year Quarter Zone Bait Hookdense Lites zone*lites quarter*zone year*bait year*quarter

Table 5. *Generalized linear model selection procedure results for proportion positive hauls from the observer data using identified billfish (BUM, WHM, and SAI) plus unidentified billfish. In this case, the data (successful hauls) are modeled as a Binomial distributed response with a logit link.*

OBSERVER proportion positive		**BILLFISH**			
model	**df**	**deviance**	**dev/df**	**LL**	**change LL/DF**
null	1204	1663.30	1.38	-831.65	
Year quarter zone	1193	1475.20	1.24	-737.60	
Year quarter zone time	1192	1454.21	1.22	-727.11	10.49
Year quarter zone bait	1192	1456.35	1.22	-728.18	9.42
Year quarter zone lites	1191	1443.73	1.21	-721.87	7.87
Year quarter zone depth	1192	1472.23	1.24	-736.12	1.48
Year quarter zone hookdense	1192	1473.64	1.24	-736.82	0.78
Year quarter zone time	1192	1454.21	1.22	-737.60	
Year quarter zone time hookdense	1191	1445.08	1.21	-722.54	15.06
Year quarter zone time bait	1191	1445.86	1.21	-722.93	14.67
Year quarter zone time depth	1191	1450.02	1.22	-725.01	12.59
Year quarter zone time lites	1190	1427.03	1.20	-713.51	12.04
Year quarter zone time hookdense	1191	1445.08	1.21	-722.54	
Year quarter zone time hookdense bait	1190	1435.38	1.21	-717.69	4.85
Year quarter zone time hookdense lites	1189	1426.57	1.20	-713.28	4.63
Year quarter zone time hookdense depth	1190	1441.22	1.21	-720.61	1.93
Year quarter zone time hookdense bait	1190	1435.38	1.21	-717.69	
Year quarter zone time hookdense bait lites	1188	1418.73	1.19	-709.36	4.16
Year quarter zone time hookdense bait depth	1189	1432.51	1.20	-716.26	1.43
Year quarter zone time hookdense bait lites	1188	1418.73	1.19	-709.36	
Year quarter zone time hookdense bait lites depth	1187	1416.28	1.19	-708.14	1.22
Year quarter zone time hookdense bait lites	1188	1418.73	1.19	-709.36	
Year quarter zone time hookdense bait lites zone*lites	1186	1395.74	1.18	-697.87	5.75
Year quarter zone time hookdense bait lites zone*time	1187	1409.02	1.19	-704.51	4.85
Year quarter zone time hookdense bait lites bait*lites	1186	1406.49	1.19	-703.25	3.06
Year quarter zone time hookdense bait lites year*quarter	1168	1355.93	1.16	-677.96	1.57
Year quarter zone time hookdense bait lites year*zone	1181	1397.54	1.18	-698.77	1.51
Year quarter zone time hookdense bait lites time*hookdense	1187	1415.72	1.19	-707.86	1.51
Year quarter zone time hookdense bait lites time*bait	1187	1416.17	1.19	-708.08	1.28
Year quarter zone time hookdense bait lites time*lites	1186	1413.70	1.19	-706.85	1.26
Year quarter zone time hookdense bait lites hookd*lites	1186	1413.87	1.19	-706.93	1.21
Year quarter zone time hookdense bait lites zone*hookdense	1187	1416.75	1.19	-708.38	0.99
Year quarter zone time hookdense bait lites year*hookdense	1181	1405.10	1.19	-702.55	0.97
Year quarter zone time hookdense bait lites zone*bait	1187	1417.07	1.19	-708.53	0.83
Year quarter zone time hookdense bait lites quarter*lites	1182	1408.94	1.19	-704.47	0.82
Year quarter zone time hookdense bait lites year*lites	1174	1396.28	1.19	-698.14	0.80
Year quarter zone time hookdense bait lites year*time	1181	1408.48	1.19	-704.24	0.73
Year quarter zone time hookdense bait lites year*bait	1182	1410.98	1.19	-705.49	0.65
Year quarter zone time hookdense bait lites quarter*hookdense	1185	1416.01	1.19	-708.01	0.45
Year quarter zone time hookdense bait lites quarter*zone	1185	1416.08	1.20	-708.04	0.44
Year quarter zone time hookdense bait lites quarter*time	1185	1416.57	1.20	-708.29	0.36
Year quarter zone time hookdense bait lites quarter*bait	1185	1416.81	1.20	-708.40	0.32
Year quarter zone time hookdense bait lites hookdense*bait	1187	1418.42	1.19	-709.21	0.15

Final Model BIL = Year Quarter Zone Time Hookdense Bait Lites